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METHOD OF REINFORCING A TOWER

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H-382247.2

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Related Applications

[0001] The present application claims the benefit of the filing date of U.S. provisional patent application serial no. 60/434,479, filed on 12/18/2002, the disclosure of which is incorporated herein by reference.

Field of Invention

[0002] The present invention relates generally to tower construction and reinforcement and more specifically to a reinforced tower structure and method and system for reinforcing metal towers, including guy towers and monopole towers.

Background of the Invention

[0003] There are many towers including guy towers and monopole towers used to support communications antenna, power transmission lines and/or other devices such as lights for highway or area illumination. Generally, governmental approval is required for location specific authorization to construct and maintain a tower of a given height. This is particularly true for sites where communications towers are located. The required approval from governmental agencies has already been obtained for many existing communications towers in many countries including for many towers in the US. In

recent years, wireless communication using communication antennas supported on towers has increased exponentially, with a corresponding increase in the number of antennas that the existing towers are called upon to support. It has been discovered by applicant that there is a need for increasing the load carrying capacity of existing towers and for a low cost method and structure for tower reinforcement to increase the strength of existing and newly constructed towers.

Brief Description of the Drawings

[0004] Fig. 1 is a schematic side view of a guy tower in the process of being reinforced according to an embodiment of the invention.

[0005] Fig. 2 is a partial enlarged side view of the reinforced tower formed according to the method of Fig. 1.

[0006] Fig. 3 is a horizontal cross-section taken along section line 3-3 of Fig.1.

[0007] Fig. 4 shows a side elevation view of the reinforced guy tower of Fig. 1 with a plurality of antennas and support structures attached;

[0008] Fig. 5 is a side view of a metal monopole tower reinforced according to an alternative embodiment of the present invention.

[0009] Fig. 6 is a cross-section taken along section line 6-6 of Fig. 5.

[00010] Fig. 7 is a horizontal cross-section taken along section line 6-6 of Fig. 5.

Detailed Description

[00011] In Fig. 1, a guy tower 10 is shown in a process of being reinforced according to one embodiment of the invention. A reinforcement column 12 is formed by applying a reinforcing material 14 to a portion of a metal frame 16 of the tower 10 so that the portion of the metal frame 16 is embedded in the reinforcing material 14. For example. the applied reinforcing material 14 is a concrete reinforcing material, molded, or otherwise shaped, to form the reinforcement column 12 extending along and having a portion of the frame 16 of the tower 10 embedded therein. The reinforcing material 14 is in a fluid state when it is applied, such as a liquid material, a flowable material or a

plastically deformable material, as for example wet concrete cement. A lower portion 12a of the reinforcement column 12 is shown having been formed.

[00012] The next higher portion 12b is shown in the process of being formed and to this end a mold 18 extends around this next higher portion 12b.

[00013] In the process of forming each portion of the column 12, the mold 18 is formed around a portion of the tower 10. The mold 18 is constructed of closeable parts 18a and 18b, releasably held together along a front vertical seam 20a and a back vertical seam 20b, as by hinges, clamps, bolts or other fasteners, to provide a hollow mold chamber when closed. The mold 18 is initially positioned and closed around a lower frame portion 16a of the tower 10 so that a lower end 22 of the mold 18 is closed by a surface 24, such as the ground or a platform, surrounding the base 26 of the tower 10 at the location where the tower 10 is constructed. Reinforcing material 14 is poured into the mold 18 so that the lower frame portion 16a of the tower 10 is embedded in the reinforcing material 14 and is held in place and shaped by the mold 18 while solidifying to form a column section 12a of the reinforcement column 12 having the lower frame portion 16a of the tower 10 embedded therein. The mold 18 is released from the column 12 by opening the parts 18a and 18b of mold 18.

[00014] To increase the height of the reinforcement column 12, additional column sections 12b and etc. are added until a desired total height is reached. When the column section 12a is at least partially solidified, it has sufficient strength to support the load involved when the next higher column section 12b is molded. The mold 18 is removed from the lower section 12a of reinforcement column 12 and is moved, repositioned and closed around a next higher frame portion 16b of the tower 10. The parts 18a and 18b of mold 18 are closed together along the front and back vertical seams. The mold 18 is also closed at its lower end 22 by a top portion of the lower column section 12a. The top end 28 of the mold 18 is opened to receive the reinforcing material 14. A small length of overlap between the mold 18 and the previous lower section 12a facilitates smooth molding and proper alignment around the tower 10 for forming the next column section 12b. The tower 10 has a plurality of guy wires 30and they are temporarily detached and then reattached at connectors 32 secured to the reinforcement column 12 at the appropriate height The reinforcement column 12 is

shown extending partially up the tower 10 and it will be understood that the reinforcement column 12 may extend to the top 30 of the tower 10 or to any desired intermediate height.

[00015] The reinforcing material 14 is conveniently supplied to the location of the tower 10 with a supply vehicle 34. The reinforcing material 14 is applied onto the tower frame 16 and into the mold 18 with an application mechanism 36. For example, the application mechanism 36 includes a mixer 38, a hopper 40, a pump 42 and a pumping hose 44. It will be understood that to elevate the reinforcing material 14 to the required height for applying it to the frame 16 of the tower 10, additional or alternative types of equipment might be used. For example, multistage pumping, elevated scaffolding, mechanical lifts, hydraulic lifts, crane lifted buckets or other devices and methods for raising the reinforcing material 14 can be used. This becomes particularly important when very tall towers are reinforced and where the reinforcing material 14, such as wet concrete cement, is very heavy when in a fluid state.

[00016] Tension cables 46 are used for strengthening the reinforcement column 12. The tension cables 46 are spaced circumferentially around the tower 10, supported from above by a guide mechanism 48. For example, the guide mechanism 48 is held above the highest section of the reinforcement column 12 that is being molded and includes a plurality of pulleys 50 spaced circumferentially around the tower 10. The tension cables 46 are supported from the pulleys 50 and hang vertically along the tower 10 inside of the mold 18. Each tension cable 46 is pulled taught using a winch 52 and the guide mechanism 48 so that the plurality of tension cables 46 are parallel to each other at the desired circumferentially spaced locations inside of the mold 18 and around the tower 10. Although only one winch 52 is shown it will be understood that a plurality of winches 52 are used corresponding to the number of tension cables 46. The tension cables 46 are molded in place within the reinforcement column 12.

[00017] To facilitate construction the mold 18 is provided with a plurality of closable openings 56 circumferentially spaced around one end 22 of the mold 18 to permit the ends 58 of cables 46 to extend out through the molded sides of the reinforcement column 12. The ends 58 of the tension cables 46 are extended out through the openings 56, and the openings 56 are covered so that the applied reinforcing material

14 will not freely escape through the openings 56. The tensioners 54 are attached to the cable ends 58. The cable ends 58 and the tensioners 54 are thus accessible for post tensioning when the mold 18 is removed.

[00018] Fig. 2 shows the reinforcement column 12 formed according to the method of Fig. 1. The tension cables 46 are cut loose at the top 28 of the tower 12 at 46a and from the winches 52 at 46b after the tension cables 46 are molded in place. Each tension cable 46 is anchored at an end 60 to the top 28 of the reinforcement column 12.

[00019] The plurality of tensioners 54 are attached to ends 58 of the tension cables 46, circumferentially spaced around the base 26 of the reinforcement column 12. The tensioners 54 are used to apply post tension to the tension cables 46 thereby providing compression to the reinforcement column 12. For example, the tensioners 54 may include threaded cable attachments by which the tension cables 46 can be placed in tension at the appropriate time and with the appropriate force so that the reinforcement column 12 is compressed between the anchored ends 60 and the opposite ends 58 of tension cables 46 for increased strength.

[00020] Fig 3 shows the frame 16 of the guy tower 10 has a triangular shape metal frame or grid that is embedded in the reinforcement column 12 according to the invention. The plurality of tension cables 46 are shown spaced annularly around the frame 16 of the tower 10. It will be understood that towers having other shapes can also be reinforced according to the present invention.

[00021] Fig. 4 shows a completed reinforced guy tower 10A with a plurality of antenna support structures 64 attached, as by embedding, clamping or otherwise, to the exterior of the reinforcement column 12. A plurality of communications antennas 66 are held by the antenna support structures 64. Other antenna 68 and 70 are also shown attached to the guy tower 10A above the reinforcement column 12.

[00022] Fig. 5 shows an alternative embodiment of the invention in which the tower to be reinforced is a monopole tower 10B. A reinforcement column 72 is formed encapsulating the monopole tower 10B. The method of forming the reinforcement column 72 is, in many of its aspects, the same as the method of forming the reinforcement column 12 for guy tower 10A as described in connection with Figs. 1-4. A tubular metal pole 74 is provided having a multisided polygon shaped cross-section as

is typical of many existing mono-pole towers. The metal pole 74 is affixed to a base pillar 76 with fasteners such as bolts or threaded studs and nuts. The base pillar is formed of concrete and extends down into the ground a sufficient distance to support the metal pole 74 by itself. The base pillar 76 typically extends a short distance above the ground. In some instances, the base pillar 76 is level with the ground 24 or it may be sunken below the ground 24. According to the invention, a reinforcement base 78 is formed around the base pillar 76 and includes a plurality of piers 80 spaced around the base pillar 76 and extending downward into the ground 28 to provide additional support to the tower when the reinforcement column 72 is added. The piers 80 are formed by drilling holes into the ground and applying reinforcing material 14, such as concrete cement into the drilled holes.

[00023] With reference also to Fig. 6, the reinforcement base 78 and reinforcement column 72 are formed using an appropriately sized and shaped mold (not shown), into which the reinforcing material 14 is applied in a process similar to that described above with respect to the guy tower of Figs. 1- 4. The reinforcement base 78 and the piers 80 are integrally formed surrounding the base pillar 76. The molded reinforcement base 78 and particularly portions adjoining with the piers 80 and with a reinforcement column 72, may be strengthened with rebar, wire mesh, dywidag bars or other imbedded strengthening materials. The piers 80 provide additional anchoring support to the reinforcement base 78. The reinforcement base 78 also engages the base pillar 76 and the tubular metal pole 74. Engagement between the reinforcement base 78 and the base pillar 76 is made strong and substantially rigid. For example, a plurality of dywidag bars 84a, 84b are extended through the reinforcement base 78 on either side of the base pillar 76 to apply compressing force. Dywidag bars 84c and 84d, positioned orthogonally to dywidag bars 84a and 84b, also apply compressing force to the reinforcement base 78. Sufficient force is placed on the reinforcement base 78 to effectively squeeze an internal surface 86 of reinforcement base 78 onto an external surface 88 of the base pillar 76. A strong and substantially rigid frictional and mechanical engagement results.

[00024] Fig. 7 shows the internal structure of the reinforcement column 72. The metal monopole tower 10B is embedded in the reinforcing material 14. Tension cables 90 are

secured to the base pillar 76 circumferentially spaced around the reinforcement column 72 and extend vertically upward through the reinforcement column 72 as it is formed. The metal pole 74 of monopole tower 10B and the tension cables 90 are embedded into the reinforcement column 72 as it solidifies. For increased strength particularly at the junction between the reinforcement base 78 and the reinforcement column 72, a plurality of lengths of rebar 92 or other metal reinforcing bars or are embedded within the reinforcement column 72 extending into and upward from the reinforcement base 78 and spaced circumferentially around the reinforcement column 72. A wire mesh 94 is also formed into the shape of a cylinder and embedded within the column 72 extending from the reinforcement base 78 upward along the column 72. The cylinder of wire mesh 94 is supported by the lengths of rebar 92 and with studs 96 secured to the metal pole 74.

[00025] A second set of vertically disposed and circumferentially space apart lengths of rebar 98 and a second cylinder of wire mesh 100 is also shown embedded in the column 72. Interconnecting cross links 102 stabilize the wire mess cylinders 94 and 100 to each other, to the rebar 92 and 98, and to the metal pole 74 of monopole tower 10B, all embedded within the reinforcement column 72. Other reinforcing material such as rebar 104 may be embedded into the structure as appropriate for strengthening high stress areas, such as at junctions of the reinforcement base 78 and the piers 80. The embedded strengthening materials including the rebar 92 and 98, the wire mesh 96 and 100 and the cross links 102 are embedded for additional strength at each overlapping junction between the reinforcement base 78 and the reinforcement column 72 and the overlapping junctions between separately molded sections of the reinforcement column 72. The embedded strengthening materials can be applied at locations in the reinforcement column 72 where additional strength is desired or along the entire height of the reinforcement column 72.

Variations And Equivalents

[00026] It is understood that variations may be made in the foregoing without departing from the scope of the invention. For example, terms with directional connotations such as base, top, bottom, side, upper, higher, lower, outer, and inner are used in context for purposes of relative positions and the device need not be limited to absolute directions in order to fall within the scope of the invention described and claimed. While various features and embodiments are described in certain combinations and sub-combinations selected features from one embodiment may be combined with features of other embodiments without departing from certain aspects of the invention.

[00027] According to one aspect of the invention as described, a metal guy tower or a metal monopole tower is reinforced by molding or forming a concrete reinforcement column encapsulating the vertical metal frame. It will be understood that tower structures made of materials other than metal might also be reinforced by the method described without departing from certain aspects of the invention.

[00028] Although, concrete cement has been given as an example of the reinforcing material 14 that has been described in the specification above, those skilled in the art will recognize that other reinforcing material may be substituted without departing form certain aspects of the invention. Examples of other reinforcing material 14 might include polymeric material, polymeric aggregate, epoxy, other cement, composites and combinations of such materials having a fluid state that can be applied to encapsulate portions of the tower structure and a solid state that forms the reinforcement column in which the portions of the tower structure are embedded. For example, a liquid state, a flowable state or a plastic state can be applied directly to and surrounding the surfaces of the tower structure and held in place so that it solidifies or cures with the portion of the tower structure embedded therein to provide added strength in the form of a reinforcement column. For example, the reinforcing material 14 is applied to the frame 16 or pole 72, by pouring the reinforcing material into the mold 18 surrounding the frame

16 or pole 72, or by spraying the reinforcing material 14 onto the frame 16 or pole 72 and holding it in place until it solidifies.

[00029] It will be understood that many different shapes of towers, as for example triangular, rectangular, square, pentagonal, hexagonal, polygon, circular, oval and etc. may be reinforced according to the invention without departing from certain aspects of the invention. It will also be understood that other embedded strengthening materials may also be used for additional strengthening of the reinforcement column. For example, wire mesh, interconnected wires, dywidag bars and rebar can be appropriately embedded into the reinforcing material 14 as it is applied and formed into a reinforcement column.

[00030] Embedded post tension cables are described and tensioners, including a threaded tensioning attachments, are described as extending out of openings in the sides of the mold. In an alternative embodiment, the tensioners may include pre-formed metal wedge shaped channels or cups that are slipped over the ends of the tension cables with the threaded tensioning attachments also attached to the tension cables. The wedge shaped channels or cups and the tensioning attachments, each attached at one end of each of the tension cables, may be secured to the inside wall of the mold during forming of the reinforcement column. The wedge shaped channels or cups shield the tensioning mechanism from the reinforcing material as it solidifies and will remain in the mold during molding of the first section of the reinforcement column. Thus, the ends of the tension cables need not extend through openings in the sides of the mold. The pre-formed wedge shaped channels or the cups are molded into the surface of the reinforcement column, and the threaded tension attachments and the cable ends will become exposed and accessible for post tensioning or for adjustment of the tension in the tension cables when the mold is removed. Moreover the tension may be applied to the post tension cables with a mechanism other than a threaded tensioning attachment as described.

[00031] The mold 18 is depicted as a pair of cylinder halves hinged together along one vertical seam 20a and then clamped or bolted together along another vertical seam 20b. Other molds constructed having other shapes and other configurations and operational requirements might be used without departing from certain aspects of the

invention. As with embodiment for monopole reinforcement, there might also be a plurality of molds or mold sections. Alternatively, there maybe one mold or a plurality of molds one stacked upon the other before, during or after applying the reinforcing material so that a longer portion of the reinforcing column or the entire reinforcing column is formed at one time.

[00032] Other equivalents to molds positionable around a tower structure to form reinforcement columns upward along the tower might also be used. For example, a reinforcing material having a tacky plastic consistency might be applied by spraying, by toweling or otherwise applying the reinforcing material onto the tower structure, so that it holds itself in place until it solidifies to provide added strength. Alternatively, such a sprayed, troweled or otherwise applied reinforcing material might be held in place by a mold, by a wrapped sheet or film of flexible material or by adhesion of the reinforcing material to the tower structure and cohesion of reinforcing material to itself while the reinforcing material solidifies.

[00033] The molded concrete columns are shown in Fig. 1 as being formed beginning with a mold at the bottom of the tower to form a lower column section. For additional support a reinforcement base as shown for the metal monopole of a tower of Figs 4-6 might be applied to the guy tower construction of Fig. 1 and might also include anchoring piers without departing from certain aspects of the invention. Similarly, a monopole tower can be reinforced without the addition of an additional reinforcement base or without the piers shown and described above.

[00034] In an alternative embodiment a process of substantially continuous pouring, molding and curing can be used to thereby progressively form a continuous column. In either embodiment the result is the forming of a molded concrete column upward along and encapsulating the existing frame of the tower. As one section or portion of the concrete reinforcement column cures below another section or portion is formed on top of the previous section or portion. The height of the molded concrete can be increased one raised section at a time or by the use of continuous molding techniques. The total height of the reinforcement column may equal the height of the existing tower or it might only extend partially along the total vertical height depending upon the particular situation for required strength, current condition of the tower, location of existing

antenna attachments, height requirements for existing and new antennas, diameter of the concrete column, and other factors that can influence the carrying capacity.

[00035] In the case of guy towers, the guy wires may be temporarily removed as the column is formed upward and past the guy wire attachment brackets. New brackets extending through and/or molded into the concrete column are re-attached to the guy wires when the mold is removed so that the tower benefits from both the strength of the guy wire supports and also the added structural strength of the encapsulating concrete reinforcement column. It will be understood that in certain situations the reinforcement column will provide sufficient support so that some or all of the guy wires may not need to be re-attached.

[00036] It will be understood that antenna attachment mechanisms, as well as mechanisms for attaching lighting or other devices, may be molded into the concrete, may be attached to the metal structure, may be partially embedded into the column as it is formed, may be attached as by clamping or otherwise after the column is formed, or may be attached to an un-embedded portion of the tower above the reinforcement column or may be attached by any combination of the above without departing from other aspects of the invention as described herein.

[00037] In the case of a monopole the reinforcement column new antenna holding brackets or brackets for holding other devices may also be formed embedded into the reinforcement column while it is being formed or may be secured as by clamping or otherwise to the exterior surface of the reinforcement column after it is formed.

[00038] The existing tower structures, whether frame type constructions or monopole constructions, provide internal reinforcement to the molded concrete column in which the tower structures are embedded. Additionally, it has been found to be beneficial to provide a plurality of spaced apart tension cables molded into and extending vertically through the concrete column. Preferably, the cables are post tension cables to facilitate strengthening the concrete reinforcement column by compressive forces applied and distributed using the post tension cables.

[00039] Although only a few alternative embodiments of this invention have been described in detail above, those skilled in the art will readily appreciate that many other modifications are possible in the alternative embodiments without materially departing

from the novel teachings and advantages of this invention. Accordingly, all such modifications are intended to be included within the scope of this invention as claimed in the claims that follow and to which applicants may be entitled.